US010016217B2

(12) **United States Patent**
Miller

(10) **Patent No.: US 10,016,217 B2**
(45) **Date of Patent: Jul. 10, 2018**

(54) **APPARATUS AND METHODS TO INSTALL, SUPPORT AND/OR MONITOR PERFORMANCE OF INTRAOSSEOUS DEVICES**

(71) Applicant: **TELEFLEX MEDICAL DEVICES S.À.R.L.**, Luxembourg (LU)

(72) Inventor: **Larry J. Miller**, Spring Branch, TX (US)

(73) Assignee: **TELEFLEX MEDICAL DEVICES S.À.R.L.**, Luxembourg (LU)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/262,030**

(22) Filed: **Sep. 12, 2016**

(65) **Prior Publication Data**

US 2016/0374722 A1 Dec. 29, 2016

Related U.S. Application Data

(60) Continuation of application No. 12/947,312, filed on Nov. 16, 2010, now Pat. No. 9,439,667, which is a (Continued)

(51) **Int. Cl.**
A61B 17/34 (2006.01)
A61M 5/158 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61B 17/3472*** (2013.01); ***A61B 17/1637*** (2013.01); ***A61B 17/32002*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC . A61B 17/34; A61B 17/3472; A61B 17/3476; A61B 17/16; A61B 17/1637; A61M 5/158
See application file for complete search history.

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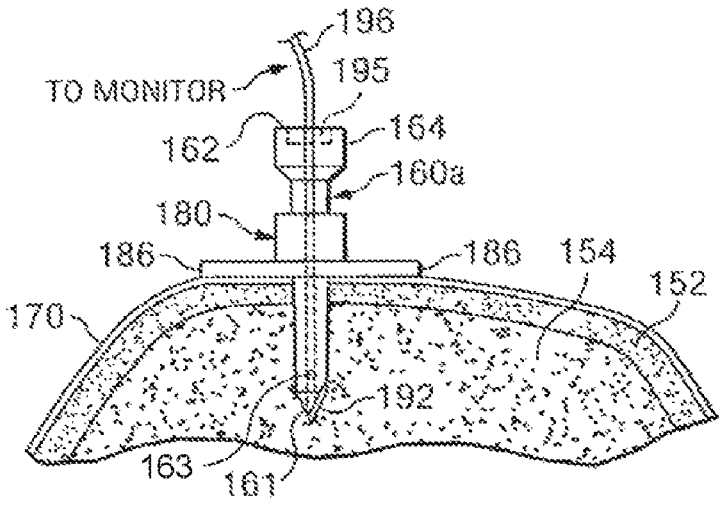
Primary Examiner — Christopher Beccia
(74) *Attorney, Agent, or Firm* — Baker & Hostetler LLP

(57) **ABSTRACT**

Apparatus and methods may be provided to monitor performance of an intraosseous device, including a system comprising an intraosseous device, a sensor contained within a tip of the intraosseous device, a monitor configured to record a signal from the sensor, and an electrical conductor coupled to the sensor and configured to transmit the signal from the sensor to the monitor. The tip of the intraosseous device may be configured to penetrate bone and bone marrow such that the tip is disposed in the bone marrow. In certain embodiments, the tip may also include a side port for delivering fluids into the bone marrow.

20 Claims, 5 Drawing Sheets



Related U.S. Application Data

division of application No. 11/461,885, filed on Aug. 2, 2006, now abandoned, which is a continuation-in-part of application No. 10/449,503, filed on May 30, 2003, now Pat. No. 7,670,328.

(60) Provisional application No. 60/384,756, filed on May 31, 2002.

(51) **Int. Cl.**

A61B 17/32	(2006.01)
A61M 5/168	(2006.01)
A61B 17/16	(2006.01)
A61B 17/3205	(2006.01)
A61B 90/11	(2016.01)
A61B 17/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 17/3476*** (2013.01); ***A61M 5/158*** (2013.01); ***A61M 5/16836*** (2013.01); *A61B 17/32053* (2013.01); *A61B 90/11* (2016.02); *A61B 2017/00022* (2013.01); *A61B 2017/00477* (2013.01); *A61B 2017/00734* (2013.01); *A61B 2017/3492* (2013.01); *A61M 2005/1581* (2013.01); *A61M 2005/1585* (2013.01); *A61M 2005/1588* (2013.01); *A61M 2205/18* (2013.01); *A61M 2205/3344* (2013.01); *A61M 2210/02* (2013.01); *A61M 2210/08* (2013.01); *A61M 2210/086* (2013.01); *A61M 2230/005* (2013.01); *A61M 2230/20* (2013.01); *A61M 2230/50* (2013.01); *A61M 2250/00* (2013.01)

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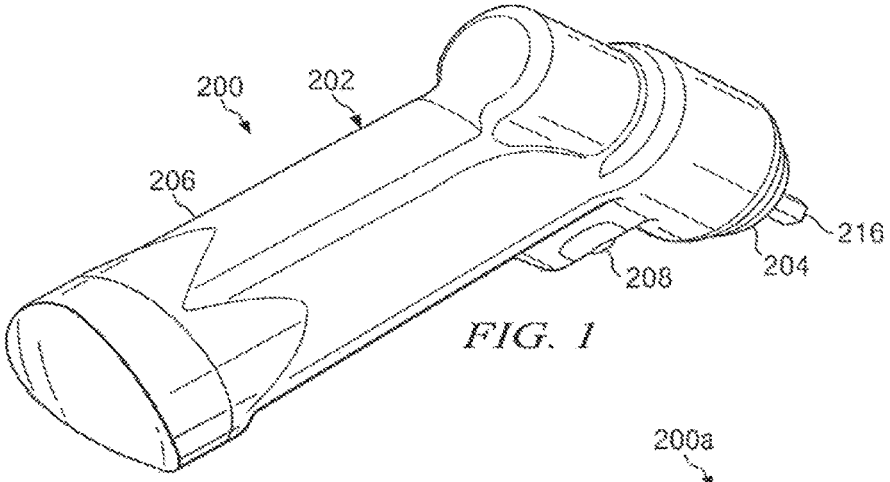

FIG. 1

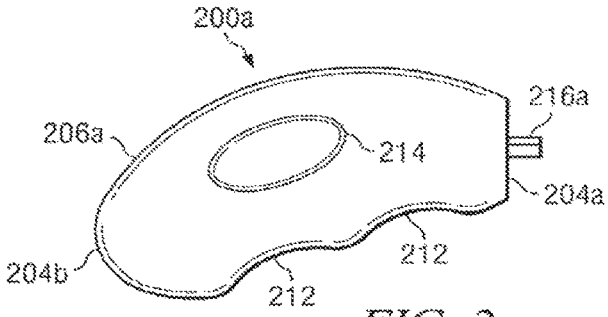

FIG. 2

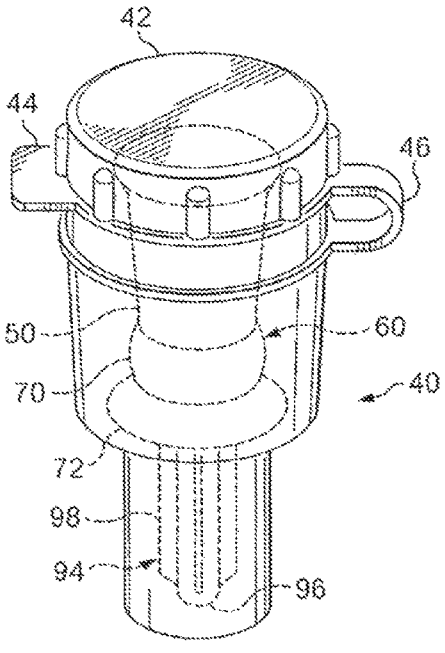

FIG. 4

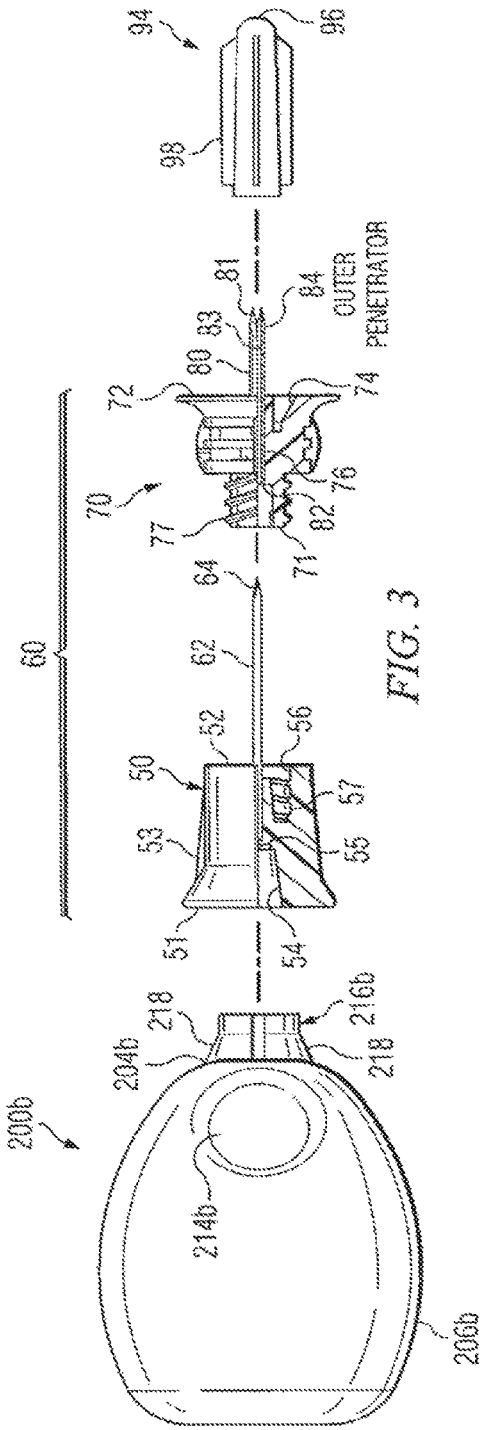

FIG. 3

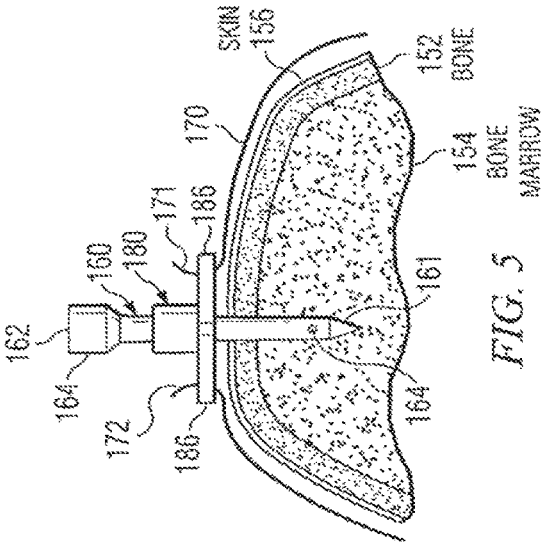

FIG. 5

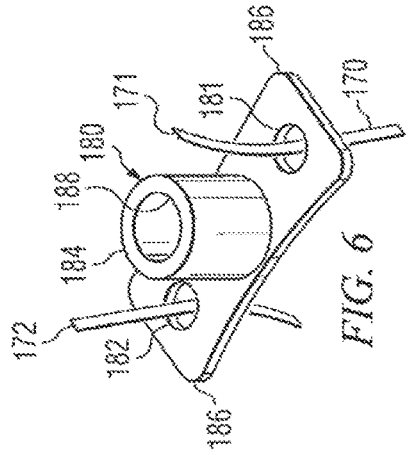

FIG. 6

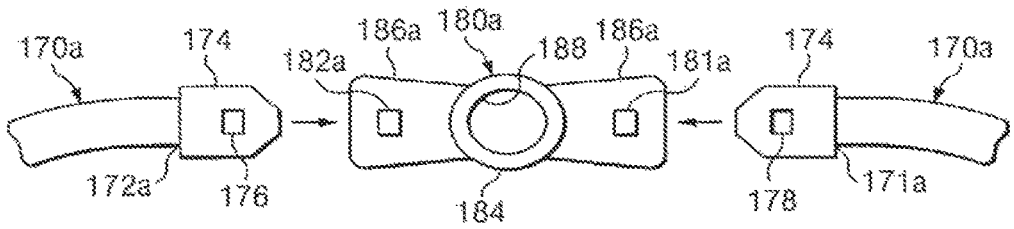

FIG. 7

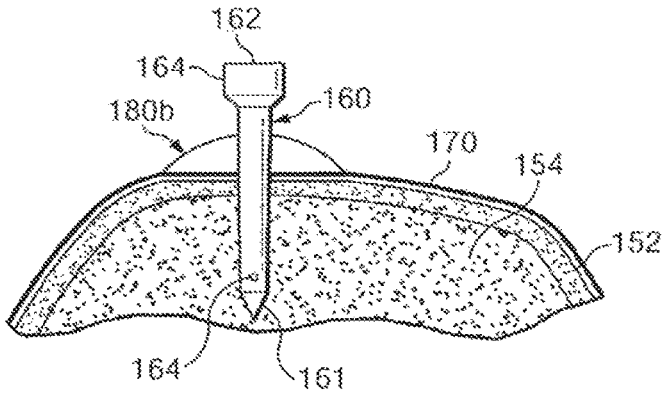

FIG. 8

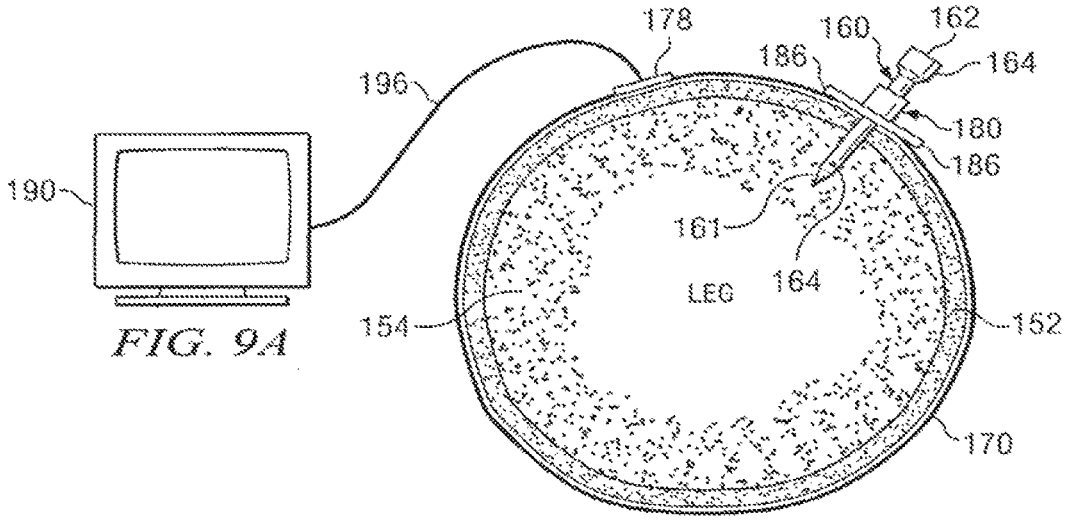

FIG. 9A

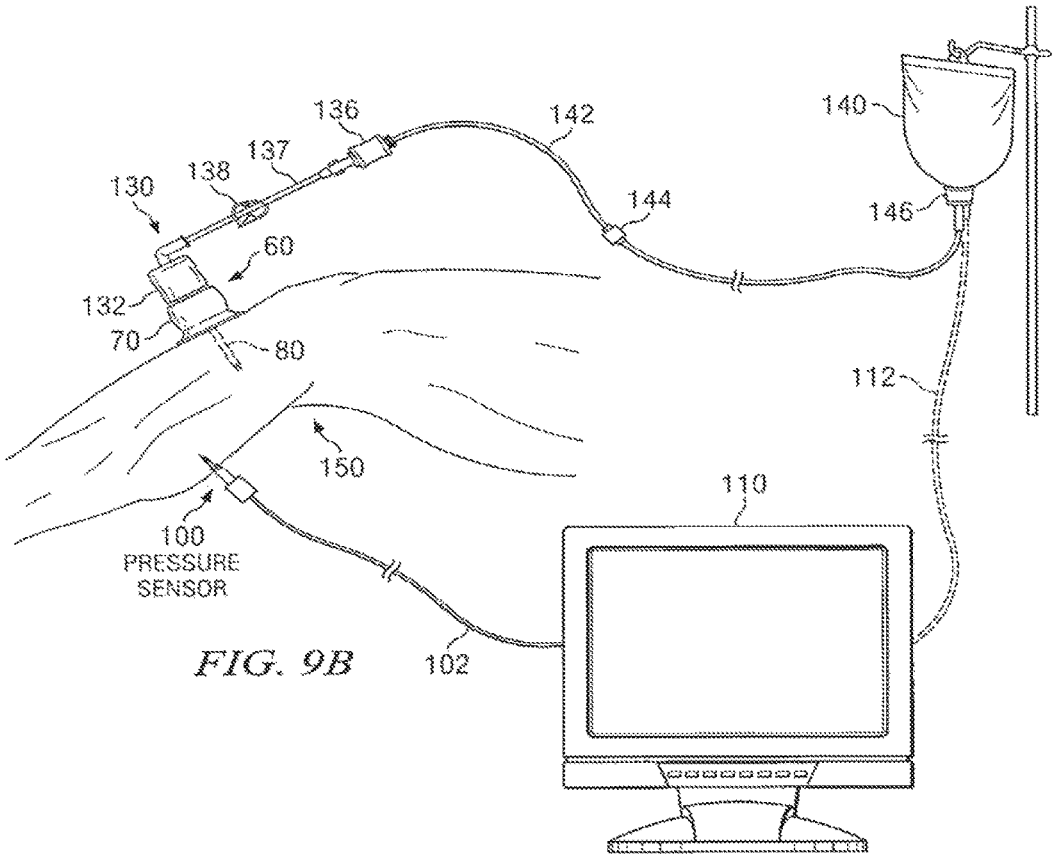

FIG. 9B

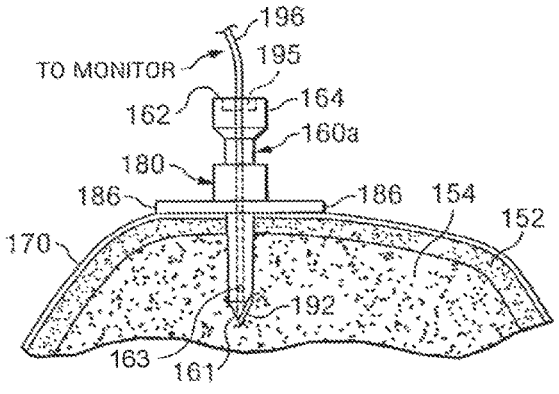

FIG. 10

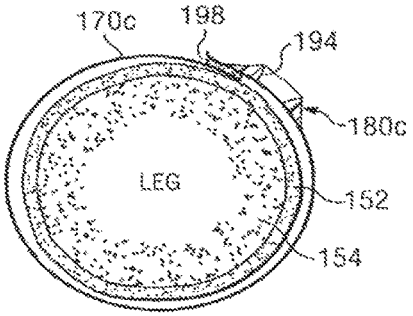

FIG. 11

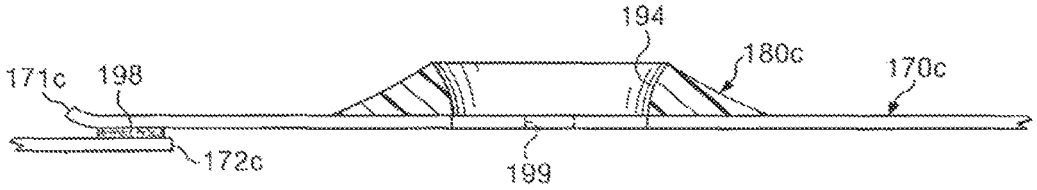

FIG. 12

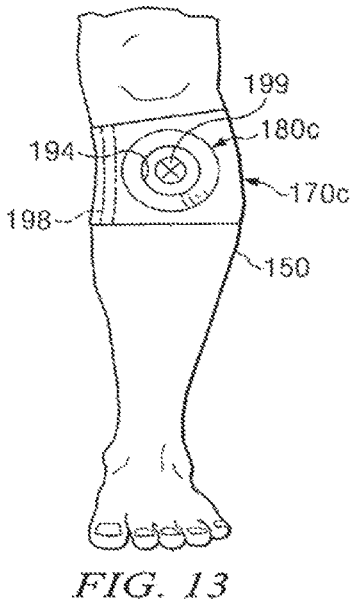

FIG. 13

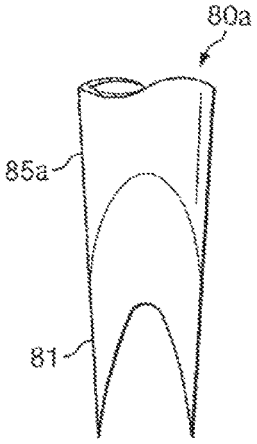

FIG. 15A

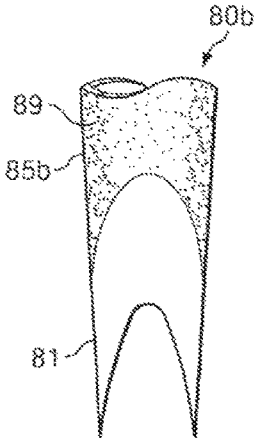

FIG. 15B

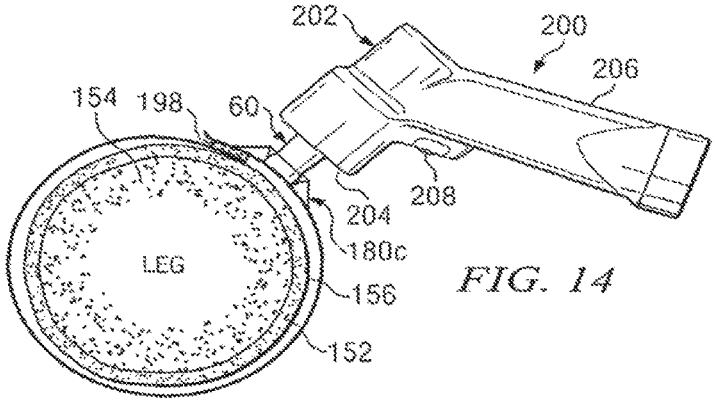

FIG. 14

APPARATUS AND METHODS TO INSTALL, SUPPORT AND/OR MONITOR PERFORMANCE OF INTRAOSSEOUS DEVICES

RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 12/947,312, filed Nov. 16, 2010, which is a divisional application of U.S. patent application Ser. No. 11/461,885, filed Aug. 2, 2006, which is a continuation-in-part application of U.S. patent application Ser. No. 10/449,503, filed May 30, 2003, now U.S. Pat. No. 7,670,328, which claims the benefit of U.S. Provisional Patent Application No. 60/384,756, filed May 31, 2002. The contents of these applications are incorporated herein in their entirety by reference.

TECHNICAL FIELD

The present disclosure is related to apparatus and methods which may be used to support an intraosseous device after insertion into a target site and/or to monitor performance of the intraosseous device while communicating fluid with bone marrow and/or other soft body tissue.

BACKGROUND

Vascular access is often essential to viability of a patient in emergency situations, during transportation to a medical facility and during treatment at the medical facility. Obtaining vascular access may be a significant problem in five to ten percent of patients of all ages and weight in pre-hospital and hospital environments. This equates to approximately six (6) million patients in the U.S. annually. For example patients suffering from conditions such as shock, cardiac arrest, drug overdose, dehydration, diabetic coma, renal failure and altered states of consciousness may have very few (if any) accessible veins.

In a hospital or similar medical facility, central line access is often an alternative to IV access. However, central line access generally takes longer, costs more, may have a higher risk of complications and requires skilled personnel to properly insert the central line. In many hospital environments, nurses and physicians are increasingly turning to intraosseous (IO) access as an alternative to IV access, rather than central lines. In pre-hospital environments, paramedics and other emergency medical service (EMS) providers are often finding that IO access may be quick, safe and effective when IV placement is challenging.

The intraosseous space typically functions as a non-collapsible vein available for infusion of drugs, blood and other fluids that reach a patient's central circulation within seconds and frequently with minimal patient discomfort. Current guidelines indicate that IO access may become the standard of care for many cardiac arrest patients further indicating that IO access is similar to central line access in efficacy and may carry less risk of complications for both patients and EMS providers.

SUMMARY

In accordance with teachings of the present disclosure, apparatus and methods are provided to facilitate access to a patient's vascular system and to monitor results of such access as appropriate. Intraosseous (IO) devices incorporating teachings of the present disclosure may be installed at selected insertion sites or target areas to infuse drugs and communicate various fluids with a patient's bone marrow. Supporting structures and attachment techniques incorporating teachings of the present disclosure may be used to enhance performance of various types of IO devices.

One aspect of the present disclosure may include providing apparatus and methods for stabilizing or securing an intraosseous device disposed in bone marrow or other soft tissue. Supporting structures, attachment devices and attachment techniques incorporating teachings of the present disclosure may be used with a wide variety of intraosseous devices.

Another aspect of the present disclosure may include the use of one or more sensors to monitor performance of an intraosseous device during infusion of drugs and/or communication of fluids with a patient's vascular system.

Another aspect of the present disclosure may include a system for monitoring performance of an intraosseous device, comprising an intraosseous device, a sensor, a monitor configured to record a signal from the sensor, and an electrical conductor coupled to the sensor and configured to transmit the signal from the sensor to the monitor. The intraosseous device may include a tip configured to penetrate bone and bone marrow such that the tip is disposed in the bone marrow, an end opposite from the tip configured to be disposed outside of the bone marrow, and a longitudinal bore extending from the tip to the end opposite from the tip. The sensor may be disposed in the tip of the intraosseous device. The sensor may be a pressure transducer configured to measure pressure.

The present disclosure may provide apparatus and methods to establish vascular access during treatment at a wide variety of locations and facilities including, but not limited to, accident sites, emergency rooms, battlefields, emergency medical services (EMS) facilities, oncology treatment centers, chronic disease treatment facilities and veterinary applications.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete and thorough understanding of the present embodiments and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** is a schematic drawing showing an isometric view of a powered driver which may be used to insert an intraosseous device at a selected site in a patient;

FIG. **2** is a schematic drawing showing a side view of a manual driver which may be used to insert an intraosseous device at a selected target area for a patient;

FIG. **3** is a schematic drawing in section and in elevation with portions broken away showing an exploded view of a manual driver and associated intraosseous device;

FIG. **4** is a schematic drawing showing an isometric view of an intraosseous device disposed in a container;

FIG. **5** is a schematic drawing in section with portions showing an intraosseous device inserted into a bone and associated bone marrow along with a supporting structure and attachment mechanism incorporating teachings of the present disclosure;

FIG. **6** is a schematic drawing showing an isometric view with portions broken away of the supporting structure and attachment mechanism in FIG. **5**;

FIG. **7** is a schematic drawing showing a plan view with portions broken away of another example of an intraosseous

device supporting structure and attachment mechanism incorporating teachings of the present disclosure;

FIG. **8** is a schematic drawing in section and in elevation with portions broken away of an intraosseous device inserted into bone marrow of a patient along with another example of a supporting structure and attachment mechanism incorporating teachings of the present disclosure;

FIG. **9**A is a schematic drawing in section with portions broken away showing an intraosseous device inserted into bone marrow of a patient along with another example of a supporting structure, attachment mechanism and monitoring apparatus incorporating teachings of the present disclosure;

FIG. **9**B is a schematic drawing in section and in elevation with portions broken away showing an intraosseous device inserted into bone marrow of a patient and a pressure monitoring device inserted into an adjacent compartment and monitoring equipment incorporating teachings of the present disclosure;

FIG. **10** is a schematic drawing in section with portions broken away showing an intraosseous device inserted into bone and associated bone marrow along with another example of a supporting structure, attachment mechanism and monitoring device incorporating teachings of the present disclosure;

FIG. **11** is a schematic drawing in section showing another example of a supporting structure and attachment mechanism incorporating teachings of the present disclosure releasably engaged with a patient's leg;

FIG. **12** is a schematic drawing in section with portions broken away of the supporting structure and attachment mechanism of FIG. **11**;

FIG. **13** is a schematic drawing showing an isometric view with portions broken away of the supporting structure and attachment mechanism of FIGS. **11** and **12** releasably attached to a patient proximate the tibia;

FIG. **14** is a schematic drawing in section showing an example of a powered driver and associated intraosseous device along with the supporting structure and attachment mechanism of FIGS. **11** and **12**;

FIG. **15**A is a schematic drawing in section with portions broken away showing another example of an intraosseous device incorporating with teachings of the present disclosure; and

FIG. **15**B is a schematic drawing in section with portions broken away showing another example of an intraosseous device incorporating with teachings of the present disclosure.

DETAILED DESCRIPTION OF THE DISCLOSURE

Preferred embodiments of the disclosure and its advantages are best understood by reference to FIGS. **1-15**B wherein like numbers refer to same and like parts.

Vascular system access may be essential for treatment of many serious diseases, chronic conditions and acute emergency situations. Yet, many patients experience extreme difficulty obtaining effective treatment because of inability to obtain or maintain intravenous (IV) access. An intraosseous (IO) space provides a direct conduit to a patent's vascular system and systemic circulation. Therefore, IO access is an effective route to administer a wide variety of drugs, other medications and fluids. Rapid IO access offers great promise for almost any serious emergency that requires vascular access to administer life saving drugs, other medications and/or fluids when traditional IV access is difficult or impossible.

The upper tibia proximate a patient's knee may often be used as an insertion site for an IO device to establish access with a patient's vascular system. The humerus in a patient's arm may also be used as an insertion site for IO access to a patient's vascular system. However, teachings of the present disclosure are not limited to treatment of human patients. Various teachings of the present disclosure may also be used during treatment of animals in a veterinary practice

IO access may be used as a "bridge" (temporary fluid and drug therapy) during emergency conditions until conventional IV sites can be found and utilized. This often occurs because fluids and/or medication provided via an IO access may stabilize a patient and expand veins and other portions of a patient's vascular system. IO devices and associated procedures incorporating teachings of the present disclosure may become the standard of care for administering medications and fluids in situations when IV access is difficult or not possible.

Intraosseous access may be used as a "routine" procedure with chronic conditions which substantially reduce or eliminate the availability of conventional IV sites. Examples of such chronic conditions may include, but are not limited to, dialysis patients, seriously ill patients in intensive care units and epilepsy patients. Intraosseous devices along with supporting structure and/or monitoring equipment incorporating teachings of the present disclosure may be quickly and safely used to provide IO access to a patient's vascular system in difficult cases such as status epilepticus to give medical personnel an opportunity to administer crucial medications and/or fluids. Further examples of such acute and chronic conditions are listed near the end of this written description.

The ability to satisfactorily insert an intraosseous (IO) device such as an IO needle at a desired insertion site may be problematic when a patient is moving or has the potential to move. Inserting an IO device in the wrong place may expose a patient to potential harm. Patient movement may be of special concern for patients suffering from status epilepticus or violent patients (drug overdoses or mental status changes) that need to be controlled for their safety and treatment. Epileptic patients may shake violently for prolonged periods which makes starting a conventional IV nearly impossible. Likewise, it may be difficult to accurately place an IO device at a desired insertion site in such patients.

Although target areas or insertion sites for successful IO placement such as a patient's tibia and humerus are often larger than target areas for placement of an IV device, problems with inserting an IO device may be minimized by using supporting structures along with attachment mechanisms and attachment techniques incorporating teachings of the present disclosure. Such supporting structures, attachment mechanisms and attachment techniques may be easy to apply, even in difficult field environments.

The term "driver" may be used in this application to include any type of powered driver or manual driver satisfactory for inserting an intraosseous (IO) device such as a penetrator assembly or an IO needle into selected portions of a patient's vascular system.

Various techniques may be satisfactorily used to releasably engage or attach an IO device and/or penetrator assembly with manual drivers and powered drivers. For some applications a powered driver or a manual driver may be directly coupled with an IO device. For other applications various types of connectors may be used to couple a manual driver or a powered driver with an IO device. A wide variety of connectors and associated connector receptacles, fittings and/or other types of connections with various dimensions

and configurations may be satisfactorily used to releasably engage an IO device with a powered driver or a manual driver.

The term "intraosseous (IO) device" may be used in this application to include any hollow needle, hollow drill bit, penetrator assembly, bone penetrator, cannula, trocar, inner penetrator, outer penetrator, IO needle or IO needle set operable to provide access to an intraosseous space or interior portions of a bone. A wide variety of trocars, spindles and/or shafts may be disposed within a cannula during installation at a selected target site. Such trocars, spindles and shafts may also be characterized as inner penetrators. A cannula may be characterized as an outer penetrator.

The term "fluid" may be used within this patent application to include any liquid including, but not limited to, blood, water, saline solutions, IV solutions, plasma or any mixture of liquids, particulate matter, dissolved medication and/or drugs appropriate for injection into bone marrow or other target sites. The term "fluid" may also be used within this patent application to include body fluids such as, but not limited to, blood and cells which may be withdrawn from a target site.

Various features of the present disclosure may be described with respect to powered driver **200** and/or manual drivers **200***a* and **200***b*. Various features of the present disclosure may also be described with respect to intraosseous devices **60**, **160** and **160***a*. However, supporting structures, attachment mechanisms and attachment techniques incorporating teachings of the present disclosure may be satisfactorily used with a wide variety of drivers and intraosseous devices. The present disclosure is not limited to use with intraosseous devices **60**, **160** or **160***a* or drivers **200**, **200***a* or **200***b*.

Powered driver **200** may include housing **202** with various types of motors and/or gear assemblies disposed therein (not expressly shown). A rotatable shaft (not expressly shown) may be disposed within housing **202** and connected with a gear assembly (not expressly shown). Various types of fittings, connections, connectors and/or connector receptacles may be provided at one end of the rotatable shaft extending from end **204** of housing **202**.

For some applications pin type fitting or connector **216** may be formed on the one end of the rotatable shaft. A matching box type fitting or connector receptacle may be provided on an intraosseous device so that connector **216** of powered driver **200** may be releasably engaged with the intraosseous device. For some applications, connector **216** may have a pentagonal shaped cross section with tapered surfaces formed on the exterior thereof.

Handle **206** may include a battery (not expressly shown) or other power source. Handle **206** may also include trigger assembly **208** for use in activating powered driver **200**. Examples of powered drivers are shown in pending patent application Ser. No. 10/449,503 filed May 30, 2003 entitled "Apparatus and Method to Provide Emergency Access To Bone Marrow," now U.S. Pat. No. 7,670,328; Ser. No. 10/449,476 filed May 30, 2003 entitled "Apparatus and Method to Access Bone Marrow," now U.S. Pat. No. 7,699, 850; and Ser. No. 11/042,912 filed Jan. 25, 2005 entitled "Manual Intraosseous Device," now U.S. Pat. No. 8,641, 715.

FIG. **2** shows one example of a manual driver which may be satisfactorily used to insert an intraosseous device into a selected target area. For this embodiment manual driver **200***a* may be generally described as having handle **206***a* with a "pistol grip" configuration. Handle **206***a* have an ergonomical design with finger grips **212** and one or more finger rests **214**.

Connector **216***a* may extend from first end **204***a* of handle **206***a*. Connector **216***a* may have a configuration and dimensions similar to previously described connector **216**. However, manual drivers may be provided with a wide variety of connectors and/or connector receptacles.

FIG. **3** is a schematic drawing showing an exploded view of a manual driver and a penetrator assembly which may be used to provide access to a patient's vascular system. For embodiments such as shown in FIG. **3**, manual driver **200***b* may be described as having a generally bulbous or oval shaped handle **206***b* with one or more finger rests **214***b* disposed on the exterior thereof. Connector **216***b* may extend from end **204***b* of manual driver **200***b* for releasable engagement with IO device or penetrator assembly **60**.

Connector **216***b* may include multiple segments or wedges sized to be received within corresponding portions of a connector receptacle. A drive shaft (not expressly shown) may also be disposed within wedges **218**. Various details concerning this type of connector and connector receptacle are discussed in more detail in pending U.S. patent application Ser. No. 11/042,912 filed Jan. 12, 2005, entitled "Manual Intraosseous Driver," now U.S. Pat. No. 8,641,715.

Penetrator assembly or IO device **60** may include connector **50** and hub **70**. Connector **50** may be described as having a generally cylindrical configuration defined in part by first end **51** and second end **52**. First end **51** may have a connector receptacle disposed therein and sized to receive connectors **216**, **216***a* and/or **216***b*.

First end **51** may include opening **54** formed with various configurations and/or dimensions. For some applications opening **54** may be sized to receive portions of a drive shaft. One or more webs (not expressly shown) may be formed in end **51** extending from opening **54**. Open segments or void spaces (not expressly shown) may be formed between such webs. Respective segments **218** extending from adjacent portions of handle **200***b* may be releasably engaged with such webs and void spaces. Opening **54** and associated webs may be used to releasably engage connector **50** with either a manual driver or a powered driver.

The configuration and dimensions of opening **54** may be selected to be compatible with releasably engaging connector **50** of penetrator assembly **60** with connector **216***b* extending of manual driver **200***b*. For some applications metallic disk **55** may be disposed within opening **54** for use in releasably engaging penetrator assembly **60** with a magnet (not expressly shown) disposed on the end of connector **216**, **216***a* or **216***b*.

For some applications exterior portion of connector **50** may include an enlarged tapered portion adjacent to first end **51**. A plurality of longitudinal ridges **53** may also be formed on the exterior of connector **50** proximate first end **51**. The enlarged tapered portion and/or longitudinal ridges **53** may allow an operator to grasp associated penetrator assembly **60** during attachment with a driver and may facilitate disengagement of connector **50** from hub **70** after outer penetrator or cannula **84** has been inserted into a bone and associated bone marrow.

Second opening **56** may be formed in second end **52** of connector **50**. For example threads **57** may be formed on interior portions of opening **56** extending from second end **52**. Threads **57** may be sized to engage threads **77** formed on an exterior portion of hub **70**. Threads **57** and **77** may be characterized as forming portions of a Luer lock connection.

However, the present disclosure is not limited to threads **57** and **77**. Various types of releasable connections including, but not limited to, other types of Luer lock connections may be formed on adjacent portions of connector **50** and hub **70**.

Trocar or inner penetrator **62** may be securely engaged with connector **50** extending from second end **52**. The dimensions and configuration of inner penetrator **62** may be selected to allow inner penetrator **62** to be slidably inserted into longitudinal bore **83** of outer penetrator or cannula **80**. Trocar **62** may include first end or tip **64**. The dimensions and configuration of tip **64** may be selected to accommodate inserting penetrator assembly **60** into bone and associated bone marrow at a selected target area in a patient.

Hub **70** may include first end **71** and second end **72**. First end **71** of hub **70** may have a generally cylindrical pin-type configuration compatible with releasably engaging hub **70** with second end or box end **52** of connector **50**. As previously noted, threads **77** formed adjacent to end **71** of hub **70** may be releasably engaged with threads **57** formed on interior portions of opening **56** of connector **50**.

For some applications second end **72** of hub **70** may have the general configuration of a flange. The dimensions and configuration of second end **72** of hub **70** may be varied to accommodate various insertion sites for an IO device. Hub **70** may be formed with a wide variety of flanges or other configurations compatible with contacting a patient's skin adjacent a desired insertion site.

Passageway **76** may extend from first end **71** through hub **70** to second end **72**. Portions of passageway **76** extending from second end **72** may have dimensions selected to be compatible with securely engaging exterior portions of outer penetrator or cannula **80** with hub **70**. Second end **82** of cannula **80** may be disposed within passageway **76** between first end **71** and second end **72**. First end **81** of cannula **80** may extend from second end **72** of hub **70**. Portions of passageway **76** extending from first end **71** of hub **70** may have an enlarged inside diameter to accommodate attachment with various types of fluid connectors. For example, see FIG. **9**B.

Cannula or outer penetrator **80** may have longitudinal bore **83** extending from first end **81** to second end **82**. Exterior dimensions of trocar or inner penetrator **62** are preferably selected to allow inner penetrator **62** be inserted through outer penetrator **80** with first end **64** of inner penetrator **62** generally aligned with first end **81** of outer penetrator **80** after threads **77** have been engaged with threads **57**.

Tip **81** of outer penetrator **80** and/or tip **64** of inner penetrator **62** may be operable to penetrate bone and associated bone marrow. The configuration of tips **81** and **64** may be selected to penetrate a bone, bone marrow and other portions of a patient's body with minimum trauma. For some applications tip **64** of inner penetrator **62** may have a generally trapezoid shape with one or more cutting surfaces.

For some applications tips **81** and **64** may be ground together as a single unit during an associated manufacturing process. Providing a matching fit allows respective tips **81** and **64** to act as a single drilling unit to minimize damage as portions of penetrator assembly **60** are inserted into a bone and associated bone marrow.

Inner penetrator **62** may sometimes include a longitudinal groove (not expressly shown) that runs along one side of inner penetrator **62** to allow bone chips and/or tissue to exit an insertion site as penetrator assembly **60** is drilled deeper into an associated bone. Outer penetrator **80** and/or inner penetrator **62** may be formed from various materials including, but not limited to, stainless steel, titanium or any other material having suitable strength and durability to penetrate bone and associated bone marrow. The combination of hub **70** with cannula **80** may sometimes be referred to as an "intraosseous needle." The combination of trocar **62** with cannula **80** may sometimes be referred to as a "penetrator set" or an "IO needle set."

Hub **70** and particularly flange **72** may be used to stabilize intraosseous device **60** after insertion into a selected target area of a patient. Second end **52** of connector **50** may be releasably engaged from first end **71** of hub **70** after insertion of outer penetrator **80** into associated bone marrow. The depth of such insertion will be dependent upon the different distance between tip **81** of cannula **80** and flange **72** of hub **70**. Various types of tubing may then be engaged with threads **77** formed on the exterior of hub **70** proximate first end or pin end **71**.

Annular slot or groove **74** may be formed within second end **72** and sized to receive one end of protective cover or needle cap **94**. Slot or groove **74** may be used to releasably engage cover **94** with penetrator assembly **60**. For some applications cover **94** may be described as a generally hollow tube having rounded end or closed end **96**. Cover **94** may be disposed within annular groove **74** to protect portions of outer penetrator **80** and inner penetrator **62** prior to attachment with a manual driver or a powered driver. Cover **94** may include a plurality of longitudinal ridges **98** formed on the exterior thereof. Longitudinal ridges **98** may cooperate with each other to allow installing and removing cover or needle cap **94** without contaminating portions of an associated penetrator needle or IO device. Cover **94** may be formed from various types of plastics and/or metals.

Container **40** as shown in FIG. **4** may include lid **42** along with tab **44**. Tab **44** may be configured to allow lid **42** to be flipped open with one or more digits of an operator's hand. With lid **42** open, an operator may releasably engage a driver with an IO device disposed in container **40**. For example, connector **216** of powered driver **200** may be releasably engaged with connector receptacle **54** of penetrator assembly **60**. FIG. **2**. Flexible connector **46** may be used to retain lid **42** with container **40** after lid **42** has been opened.

Various examples of supporting structures, supporting devices, attachment mechanisms and attachment techniques incorporating teachings of the present disclosure are shown in FIGS. **5-14**. Various features of the present disclosure may be discussed with respect to bone **152** and associated bone marrow **154** as shown in FIGS. **5**, **8**, **9**A-**11** and **14**. Bone **152** and bone marrow **154** may be representative of a portion of a patient's leg. Various examples of monitoring apparatus, equipment, devices, techniques and methods to evaluate performance of an intraosseous device are shown in FIGS. **9**A, **9**B and **10**.

One example of an intraosseous device inserted into bone and associated bone marrow along with a supporting structure and attachment mechanism incorporating teachings of the present disclosure is shown in FIG. **5**. For this example, the intraosseous device may be generally described as intraosseous (IO) needle **160** having a hollow, longitudinal bore extending therethrough (not expressly shown). First end or tip **161** of IO needle **160** may be designed to drill or cut through bone **152** and penetrate associated bone marrow **154**. Tip **161** may be open to allow communication of fluids with bone marrow **154**. Also, one or more side ports **163** may be formed in IO needle **160** to allow communication of fluids therethrough.

Second end **162** of IO needle **160** may have various types of connections including, but not limited to, a conventional Luer lock connection (not expressly shown) associated with

supplying IV fluids and/or medications to a patient. For embodiments such as shown in FIGS. **5**, **8**, **9**A and **10** connector receptacle **164** may be formed adjacent to second end **162**. Connector receptacle **164** may have an enlarged outside diameter as compared with other portions of IO needle **160**.

For some applications IO device **160** may have a tapered exterior to provide a better or tighter fluid seal with adjacent portions of bone **152** to prevent extravasation. Prior IO needles typically have a uniform outside diameter between fourteen (14) gauge (large) and eighteen (18) gauge (small). Increases in outside diameter or taper of IO device **160** may be selected to provide an enhanced fluid seal between exterior portions of IO device **160** and bone **152**. The increases in the outside diameter or taper of IO device **160** may be limited to prevent fracture of bone **152** as IO device **160** is advanced into bone **152** and bone marrow **154**. For some applications, IO device **160** may have a tapered outside diameter that increases by approximately one (1) gauge size. For example IO device **160** may have a sixteen (16) gauge diameter proximate first end **161** and a fifteen (15) gauge diameter proximate connector receptacle **164**. However, other gauges and tapers may also be used.

The result of forming a good fluid seal between exterior portions of IO device **160** and adjacent portions bone **152** is that fluids and/or drugs injected through IO device **160** will flow into the patient's vascular system. The result of a broken fluid seal (or loose fluid seal) may be that some of the fluid will extravasate (leak) into surrounding tissues and may cause a compartment syndrome. This condition is a potentially serious complication associated with the use of IV and IO devices. Pressure from leaking fluid may build up in a limb or other portions of a patient's body which have only limited capacity for expansion. Problems resulting from excessive fluid pressure in tissue adjacent to an IV or IO insertion site will be discussed later.

Supporting structure **180** and attachment mechanism **170** such as shown in FIGS. **5** and **6** may be used with IO devices **60**, **160** and **160***a* or any other type of IO device. Attachment mechanism **170** may be formed from various types of elastomeric and/or nonelastomeric materials compatible with contacting skin **156** and other soft tissue covering a patient's bone at a selected insertion sight or target area. The dimensions and configuration of attachment mechanism **170** may be selected to form satisfactory engagement with adjacent portions of leg **150**, an arm, or other selected target site for providing access to a patient's vascular system.

For some applications attachment mechanism **170** may be generally described as a strap having first end **171** and second end **172** sized to be inserted through holes **181** and **182** of supporting structure **180**. Strap **170** and supporting structure **180** cooperate with each other to prevent accidental removal or withdrawal of IO needle **160** from an insertion site. Strap **170** and supporting structure **180** also cooperate with each other to prevent excessive movement or rocking of IO device **160** relative to the insertion site.

Supporting structure **180** may include relatively short, hollow cylinder **184** with a pair of flaps, tabs or wings **186** extending therefrom. Holes **181** and **182** may be formed in respective tabs **186**. Tabs **186** may be formed from relatively flexible material which will conform with adjacent portions of a patient's skin, soft tissue and bone Hollow cylinder **184** may be formed from material with sufficient strength to prevent undesired movement of IO device **160**. Interior dimensions of hollow cylinder **184** may correspond generally with exterior dimensions of IO needle **160** to provide a relatively snug fit therebetween.

For some applications attachment mechanism **170** may be used to releasably engage supporting structure **180** at a desired insertion site. An intraosseous device such as IO needle **160** may then be inserted through longitudinal bore **188** of supporting structure **180**. For other applications IO needle **160** may first be inserted into bone marrow **154**. Inside diameter **188** of cylinder **184** may be selected to be compatible with the dimensions and configuration of second end **162** such that supporting structure **180** may be inserted over or releasably engaged with IO needle **160** after insertion into bone marrow **154**. For example, the dimensions of second end **162** may be substantially reduced as shown in FIG. **5**. Alternatively, cylinder **184** may be formed from material having sufficient flexibility to accommodate expanding supporting structure **180** to fit over the exterior of IO device **160**.

For embodiments such as shown in FIG. **7**, supporting structure **180***a* may include wings, tabs or flaps **186***a* which have been modified to include respective projections **181***a* and **182***a* extending therefrom. Strap **170***a* may be modified as compared with strap **170** by attaching respective buckles **174** with first end **171***a* and second end **172***a*. Each buckle **174** may include respective opening or hole **176** sized to receive associated projection **181***a* and **182***a* formed on tabs **186***a*.

Supporting structure **180***a* may be placed at an IO insertion site. Buckle **174***a* at first end **171***a* of strap **170***a* may be releasably engaged with corresponding projection **181***a*. Strap **170***a* may then be extended around patient's leg or other portions of a patient's body to allow engaging buckle **174***a* at second end **172***a* with associated projection **182***a*. For some applications, strap **170***a* may be formed from elastomeric material.

For some applications supporting structure **180***a* may be placed at an insertion site prior to installing IO device **160**. IO device **160** may then be inserted through hollow cylinder **184** of supporting structure **180***a*. For other applications an IO device with exterior dimensions and exterior configuration compatible with interior dimensions of longitudinal bore **188** of supporting structure **180***a* may first be installed at a desired insertion site. Supporting structure **180***a* may then be fitted over the installed IO device (not expressly shown) by placing the IO device through hollow cylinder **184** of supporting structure **180***a*. Buckles **174** strap **170***a* may then be engaged with respective projections **181***a* and **182***a*.

FIG. **8** shows IO needle **160** inserted into bone marrow **154**. Supporting structure **180***b* may be used to stabilize IO needle **160** and limit excessive movement relative to bone **152**. Supporting structure **180***b* may be generally described as having a domed shape configuration. The dimensions of supporting structure **180***b* may be selected to be compatible with a desired insertion site. A longitudinal bore or a longitudinal opening (not expressly shown) may extend through supporting structure **180***b*. The longitudinal bore may have dimensions compatible with exterior dimensions of IO needle **160**.

Supporting structure **180***b* may be formed from various types of semi-rigid silicone based materials and/or materials satisfactory for providing required support. A pair of holes (not expressly shown) may be provided in supporting structure **180***b* to accommodate the use of strap **170**. However, other straps such as shown in FIGS. **11**, **12** and **14** may be satisfactorily used to attach supporting structure **180** at a desired insertion site.

The muscles in a patient's limbs are typically split into respective enclosed spaces or "compartments" bound by

strong and relatively unyielding membranes of fibrous tissues (deep fascia). Such enclosed spaces may also be referred to as "fascial compartments." Fibrous tissue or membranes effectively wrap around or surround respective muscle groups attached with the same bones. For example the lower leg of humans typically has four (4) compartments. Each compartment has a respective blood and nerve supply.

Compartment syndrome (sometimes referred to as "compartmental syndrome") may be generally described as a condition associated with increased pressure within an enclosed or limited space (compartment) of a patient's body that interferes with normal circulation of fluids (blood) and tissue functions within the compartment. Compartment syndrome is of particular concern with respect to a patient's limbs (legs, feet, arms and hands). Apparatus and methods of the present disclosure are not limited to monitoring a patient's limbs for compartment syndromes.

Compartment syndromes may be further characterized as acute, chronic, or secondary. Acute compartment syndromes are generally secondary to trauma and may have significantly elevated intracompartmental pressures. Acute compartment syndrome may occur when tissue pressure exceeds venous pressure and impairs blood flow out of the compartment. Sustained elevation of tissue pressure generally reduces capillary profusion below required levels for tissue viability and may irreversibly damage muscles and nerves within an affected compartment. Compartmental syndrome may occur when tissue pressure within a compartment exceeds associated profusion pressure.

Acute compartmental syndromes may occur following bone fractures, vascular damage, crushing of a limb or other body part and other injuries. Rapid onset and decreased circulation increases the need for prompt diagnosis and sometimes surgical decompression to avoid necrosis and long-term dysfunction. Untreated acute compartment syndromes may result in loss of limb functions and/or loss of a limb.

Leakage of fluids and/or drugs from a vein into surrounding tissue during an intravenous procedure or from a bone into surrounding tissue during an intraosseous procedure may also produce a compartment syndrome. Leakage of IV and IO fluids and drugs may be referred to "extravasation." Resulting injuries and/or damage associated with extravasation may be very serious.

Chronic compartment syndromes are generally milder, recurrent and often associated with exercise, repetitive training or physical exertion. Chronic compartment syndromes usually resolve with rest but may progress to an acute form if associated physical activity is continued

Supplying fluid to bone marrow using an intraosseous device may result in increased pressure in an adjacent compartment if fluid integrity of an associate bone containing the bone marrow has been compromised. For example a vehicle accident may result in a bone fracture allowing fluid communication with an adjacent compartment. Various diseases or chronic conditions may result in deterioration of a bone and allow fluid communication between associated bone marrow and an adjacent compartment. Monitoring a patient's extremity (limb) for such pressure increases may be appropriate if damage or injury has occurred to the extremity (limb). An intraosseous injection site other than a damaged limb or extremity should generally be selected whenever possible.

Extravasation and potentially resulting compartment syndrome may be an undesired side effect of administration of fluids via intraosseous device. Extravasation may occur if there has been damage and/or deterioration of the associated bone. Extravasation may also occur if there is not a satisfactory fluid seal between exterior portions of an IO device and adjacent portions of an associated bone. The use of monitors, pressure sensors or strain gauges and other apparatus in accordance with teachings of the present disclosure may provide an early warning or early notice of possible pressure increases which may lead to undesired side effects such as compartment syndromes if not corrected.

Apparatus and methods to detect extravasation and potential compartment syndrome may be incorporated into supporting structures and/or attachment mechanism for an IO device in accordance with teachings of the present disclosure. For example, a strap may be equipped with a stain gauge or pressure sensor to detect an increase in size of a limb indicating a possible impending compartment syndrome.

FIG. **9**A shows IO device **160** seated in bone **152** and associated bone marrow **154**. Strap **170** may be placed around bone **152** and attached to supporting structure **180** as previously described. Sensor **178** may be attached to strap **170** for use in measuring various parameters associated with providing fluids and/or medications through IO device **160** to bone marrow **154**. Such parameters may include, but are not limited to, pressure and/or changes in the size of a patient's limb, temperature and/or pulse rate. For example, sensor **178** may be a strain gauge operable to measure and detect increased stress placed on strap **170** by swelling, expansion or change size of a patient's limb. For some applications sensor **178** may be coupled with monitor and/or general purpose computer **190** via signal wire **196**. When monitor **190** detects a preset value for one or more of these parameters, an alarm may be sounded. Monitor **190** may also include one or more programs operable to stop infusion of fluids and/or medication through IO device **160** in the event one or more parameters exceeds a preset limit.

Another method of detecting a potential compartment syndrome may include directly inserted sensor into a compartment and connecting a pressure sensor with an appropriate pressure monitor. For some applications tubing may be used to connect a hollow needle with a pressure sensor. The pressure sensor may be connected with a pressure monitor. For some applications the hollow needle, tubing and pressure sensor may contain a saline solution. An increase in pressure within the compartment may be used to alert medical personnel that a serious condition may be developing.

For embodiments such as shown in FIG. **9**B cannula **80** of intraosseous device **60** may be inserted into the tibia of leg **150**. Various types of IO and IV fluid connectors may be releasably engaged with first end **71** of hub **70**. For embodiments such as shown in **9**B, right angle connector **130** may include Luer lock fitting **132** operable to be releasably engaged with first end **71** of hub **70**. Right angle connector **130** may be satisfactorily used to couple IO device **60** with various sources of medication and/or fluids. For example, IV bag **140** may be connected with right angle connector **130** using flexible tubing **142** and tubing connectors **144**. Various types of control valves and/or outlet mechanisms **146** may be used to regulate the flow of fluid from IV bag **140** through tubing **142**, right angle connector **130** to intraosseous device **60**. For some applications control valve **146** may include an electrical actuator (not expressly shown).

For embodiments such as shown in FIG. **9**B one or more sensors may be placed in a compartment of a patient's limb or extremity adjacent to an intraosseous insertion site. Such sensors may be used to detect pressure, temperature, oxygen

levels, carbon dioxide levels, lactic acid concentrations and/or concentration of drugs, medications or chemicals contained in the IV or IO fluids communicated through IO device **60**. For example, pressure sensor **100** may be inserted into a compartment of leg **150** containing an associated calf muscle to detect any increased pressure in the compartment. Such pressure increase may result from communication or extravasation of fluid between the bone marrow and the calf muscle or compartment via damaged or deteriorated portions of bone **152**.

Monitor **190** may be used to alert medical personnel that the pressure is increasing and that a serious condition such as a compartment syndrome may develop. Monitor **190** may also alert medical personnel concerning temperature changes, undesired oxygen or carbon dioxide levels or the presence of any drugs, medication or chemical associated with IV or IO fluids communicated through IO device **60**.

Various types of control mechanisms, general purpose computers and/or monitors **110** may be engaged with sensor **100**. For some applications an electrical cable or conductor **102** may be engaged with sensor **100**. For other applications (not expressly shown) sensor **100** may be a generally hollow needle. A hollow tube may connect sensor **100** with a pressure monitor.

For some applications an electrical cable or wire **112** may be connected between pressure monitor **110** and control valve **144**. When monitor **110** receives a pressure which exceeds a preselected value, control valve **146** may be activated to block or prevent further flow of fluid from IV bag **140** to intraosseous device **60**.

FIG. **10** shows IO device **160***a* inserted into bone **152** and associated bone marrow **154**. IO device **160***a* may be equipped with pressure transducer **192** proximate tip **161** to measure intraosseous pressure. For some applications, a similar needle may be placed in a leg muscle to measure intra-compartment pressure. See FIG. **9**B.

Seal assembly **195** may be used to isolate signal wire **196** so that infusions of fluids may proceed while, at the same time, measuring intravenous pressure at tip **161**. Various types of elastomeric materials may be used to form seal assembly **195**. For some applications one or more valves (not expressly shown) may also be used to isolate signal wire **196** from fluid flowing through IO device **160***a*.

Measurements from sensor **192** may be analyzed by a computer (not expressly shown) to manage changes in a patient's condition by initiating pre-set changes in infusion pressure, controlling the rate of infusion or stopping infusion all together and alerting the patient and/or medical personnel if pressure limits are exceeded.

As stated in U.S. Provisional Patent Application No. 60/384,756, in certain embodiments, a tip of a needle may contain a pressure transducer (e.g., the tip **161** of the IO device **160***a* may contain the pressure transducer **192**). The electrical wire from the transducer may exit the needle separate from a Luer lock port. The connector may be a standard Luer lock or any other conventional connector to allow monitoring of pressure directly from the fluid. Either of these models may be attached to a monitor or a computer to alert medical personnel of impending problems. Software may also be used as a servomechanism to automatically control pressure or other parameters. The probe may detect pressure, chemicals, temperature, oxygen stats, carbon dioxide levels, or lactic acid. The connector may be mechanical or electrical.

FIGS. **11**, **12** and **13** show one example of a supporting structure or guide which may be disposed at a desired insertion site such as the upper tibia proximate a patient's knee. Supporting structure or guide **180***c* may be generally described as having a dome shaped configuration with cavity or opening **194** formed therein and sized to receive an intraosseous device. For example, opening **194** may be sized to accommodate an intraosseous device such as penetrator assembly **60**. See for example FIG. **3**.

Supporting structure or guide **180***c* may be formed from various polymeric and/or thermoplastic materials having desired rigidity and strength to direct insertion of an intraosseous device at a desired insertion site. Supporting structure **180***c* may also be formed from various types of elastomeric and/or nonelastomeric materials satisfactory for use in forming a guide or supporting structure to direct insertion of an intraosseous device at a desired insertion site and/or to stabilize an IO device at an insertion site.

For some applications strap **170***c* may include one or more strips of hook and loop type material **198** (sometimes referred to as Velcro® strips) disposed proximate first end **171***c* and second end **172***c* of strap **170***c*. The configuration, size and dimensions of Velcro® strips **198** may be modified to allow strap **170***c* to releasably attach supporting structure **180***c* with a leg or other portions of a patient's body having various dimensions. For some applications supporting structure **180***c* may include target **199** disposed within opening **194** for use by an operator to more precisely direct installation of an associated IO device at a desired insertion site.

FIG. **14** shows powered driver **200** being used to insert penetrator assembly **60** at an insertion site identified by guide or supporting structure **180***c*. For some applications interior portions of opening **194** may have a generally convex configuration compatible with guiding and supporting adjacent portions of penetrator assembly **60**. Powered driver **200** may be further stabilized with various types of straps and/or medical grade tape (not expressly shown) prior to inserting penetrator assembly **60**.

Extravasation (leakage) of cytotoxic drugs into subcutaneous tissues adjacent to an insertion site during cancer treatment may be devastating. To prevent extravasation (leakage) of cytotoxic drugs or other fluids, an IO device incorporating teachings of the present disclosure may include a tapered exterior with progressively larger outside diameters to form a satisfactory fluid seal with adjacent bone. A wide variety of medically approved adhesives and sealants may also be disposed on exterior portions of an IO device to provide a satisfactory fluid seal. Methylene blue dye may be injected into an IO device to detect any fluid leak between exterior portions of the IO device and adjacent bone.

For embodiments such as shown in FIG. **15**A, IO device **80***a* may include tapered exterior **85***a* which provides a better or tighter fluid seal with adjacent portions of a bone at an insertion site to prevent extravasation. Increases in the outside diameter of IO device **80***a* may be limited to prevent fracture of a bone at an insertion site as IO device **80***a* is advanced into the bone and associated bone marrow. The increase in outside diameter **85***a* of IO device **80***a* may be selected to provide an enhanced fluid seal between tapered exterior **85***c* and adjacent portions of the bone.

IO needles are typically described as having a gauge size corresponding with the diameter. IO needles typically range with gauges between the range of eighteen (18) to fourteen (14). A fourteen gauge IO need is larger than eighteen gauge. For some applications, IO devices **80***a* and **80***b* may generally be described as an IO needle having a tapered outside diameter that increases from approximately one gauge size such as from sixteen (16) gauge adjacent first end **81** to approximately fifteen (15) gauge adjacent an associated hub.

For embodiments such as shown in FIG. **15**B, IO device **80***b* may include tapered exterior surface **85***b* with sealant layer **89** disposed thereon. A wide variety of medical grade sealants and adhesives may be satisfactorily disposed on exterior portions of IO device **80***b* including, but not limited to, silicone and methyl methacrylate. Tapered exterior **85***b* and sealant layer **89** may cooperate with each other to provide an enhanced or tighter fluid seal between adjacent portions of a bone at an insertion site to prevent extravasation. The increase in outside diameter of IO device **80***b* may be limited as previously described with respect to IO device **80***b*.

Sealant layer **89** may also be disposed on exterior portions of IO device **80**, **80***a*, **160** and **160***a* or any other IO device incorporating teachings of the present disclosure to substantially minimize or prevent extravasation The use of medical grade sealants and adhesives is not limited to IO devices having tapered, exterior surfaces.

The result of forming a satisfactory fluid seal between exterior portions of an IO device and adjacent portions a bone is that fluids and/or drugs injected through such IO devices will not leak into adjacent tissue. The result of a broken fluid seal (or loose fluid seal) may be that some of the fluid will extravasate (leak) into surrounding body tissues and may cause serious damage. IO devices **80**, **80***a*, **80***b*, **160** and/or **160***a* and any other IO device incorporating teachings of the present disclosure may also have an interior coating of Heparin or other anticoagulants to prevent clotting. An exterior coating of a suitable antibiotic to prevent infection may also be used with an IO device incorporating teachings of the present disclosure.

Examples of acute and chronic conditions which may be treated using intraosseous devices, intravenous devices and procedures incorporating teachings of the present disclosure include, but are not limited to, the following:

Anaphylaxis (epinephrine, steroids, antihistamines, fluids, and life support);

Arrhythmia (anti-arrhythmics, electrolyte balance, life support);

Burns (fluid replacement, antibiotics, morphine for pain control);

Cardiac arrest (epinephrine, atropine, amiodarone, calcium, xylocaine, magnesium);

Congestive heart failure (life support, diuretics, morphine, nitroglycerin);

Dehydration (emergency port for life support, antibiotics, blood, electrolytes);

Diabetic Ketoacidosis (life support, electrolyte control, fluid replacement);

Dialysis (emergency port for life support, antibiotics, blood, electrolytes);

Drug overdose (naloxone, life support, electrolyte correction);

Emphysema (life support, beta adrenergics, steroids);

Hemophiliacs (life support, blood, fibrin products, analgesics);

Osteomyelitis (antibiotics directly into the site of infection, analgesics);

nutrition, electrolyte correction);

Seizures (anti-seizure medications, life support, fluid balance);

Shock (life support fluids, pressor agents, antibiotics, steroids);

Sickle cell crisis (fluid, morphine for pain, blood, antibiotics); and

Trauma (emergency port for life support fluids, antibiotics, blood, electrolytes).

More than 35,000 Advanced Cardiac Life Support (ACLS) ambulances are in service in the U.S. Each is equipped with emergency drugs and devices. Most are required to carry intraosseous needles and paramedics are trained in their use for pediatric emergencies. Kits incorporating teachings of the present disclosure may be used to administer medications and treats before permanent damage to a patient occurs.

More than 4,000 emergency rooms in the U.S. are required to treat life-threatening emergencies like shock trauma and cardiac arrest. ERs are stocked with the latest devices and equipment to help patients receive state-of-the-art treatment. However, there is no more exasperating situation for the physician or potentially catastrophic condition for the critical patient, than the inability to establish intravenous access. Kits with IO devices incorporating teachings of the present disclosure may provide a simple and straightforward solution for extremely difficult clinical problems.

Hospitals are required to provide crash carts on every patient ward. It is estimated that 6,000 U.S. hospitals stock more than 60,000 crash carts. These crash carts are stocked with defibrillators, IV access devices, including central venous catheters, IV fluids and drugs for common emergencies. Nurses and other healthcare workers using these crash carts are often inexperienced in such emergencies and have difficulty establishing IV access. A kit with IO devices incorporating teachings of the present disclosure may provide the long sought IV alternative for difficult patients.

Automatic injectors are widely used in the military. During Desert Storm, combat soldiers carried an atropine auto-injector for nerve gas poisoning. Current auto-injectors are limited to intramuscular injections. The Kits with IO devices may vastly expand the scope of treatment to include intravenous drugs, without having to be skilled in the technique of intravenous insertion.

Most acute care hospitals in the U.S. operate Intensive Care Units (ICUs) for seriously ill patients. Establishing and maintaining venous access in these patients is often a challenge. IO access may be a welcome procedure for administration of drugs and fluids to these critical patients.

Ten percent of the population experience a major seizure in their lifetime and more than 2,500,000 people in the United States have epilepsy. Grand mal seizures represent one of the most dramatic events in medicine. During the seizure, which usually lasts 60 to 90 seconds, patients typically fall to the ground, become rigid with trunk and extremities extended, and shake violently. The most dreaded progression of seizures is status epilepticus, a condition defined as a continuous seizure lasting more than 30 minutes or two or more seizures that occur without full conscious recovery between attacks. Convulsive status epilepticus requires urgent, immediate treatment. Patients are at risk for serious injury, hypoxemia, circulatory collapse, permanent brain damage and death. The overall mortality of convulsive status epilepticus is up to approximately thirty-five percent (35%).

Intravenous access with a large bore needle/catheter must be established to administer anticonvulsant medications. These include a benzodiazepine followed by phenytoin and/or phenobarbitol for immediate seizure control and prevention of further seizures. There are no satisfactory oral, rectal, or intramuscular medications that will control status epilepticus.

The problem facing clinicians and paramedics treating patients with status epilepticus is the difficulty establishing venous access. Without adequate venous lines none of the effective anticonvulsants can be given. During seizures the

violent shaking makes accessing a satisfactory vein difficult. Often after the line is established, further shaking dislodges the IV or causes it to infiltrate.

Further, caregivers are at great risk of puncturing themselves with a needle when attempting to establish venous access in a patient during a seizure. Through no fault of their own, seizing patients, by jerking and thrashing around, turn the safest procedure into a terrifying venture. Doctors, nurses, and paramedics work in mortal fear of contracting AIDS and hepatitis through an inadvertent puncture with a contaminated needle.

In an attempt to solve the venous access problem, emergency physicians and intensivists have turned to establishing a central line (intravenous catheter placed in a large central vein such as the subclavian or femoral vein). However, with this method, even under ideal conditions, there is an increased incidence of serious side effects such as pneumothorax, hemothorax, inadvertent puncture of a major artery, infection, venous thrombosis, and embolus. In the case of a patient with status epilepticus, this method becomes increasingly difficult and dangerous for all of the above-mentioned reasons. Therefore, most doctors are reluctant to even attempt a central line until seizures have ceased.

Dialysis patients who often come to the emergency room in life threatening situations such as pulmonary edema (water on the lungs) or high potassium leading to cardiac arrest. These patients typically have troublesome or non-existent veins. The IO access may give these patients hope for a better quality of live and decrease their mortality.

Drug overdose victims, often comatose, generally require immediate IV access to give antidotes and life saving medications such as Narcan. These patients usually have difficult venous access due to long term abuse of their veins IO access may give these patients an alternate route for delivery of medications and fluids while improving the safety of the healthcare workers.

Trauma victims and attempted suicide patients, often in shock due to blood loss, may also require swift replacement of fluids to save vital organs. Because of the shock condition (decreased blood pressure), veins collapse and are often impossible to find IO access may save precious minutes for paramedics and trauma surgeons responsible for their care.

Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alternations can be made herein without departing from the spirit and scope of the disclosure as defined by the following claims.

The invention claimed is:

1. A system for monitoring performance of an intraosseous device, comprising:

an intraosseous device comprising:

a tip configured to penetrate bone and bone marrow such that the tip is disposed in the bone marrow;

an end opposite from the tip configured to be disposed outside of the bone marrow; and

a longitudinal bore extending from the tip to the end opposite from the tip;

a sensor contained within the tip;

a monitor configured to record a signal from the sensor; and

an electrical conductor coupled to the sensor and configured to transmit the signal from the sensor to the monitor, the electrical conductor extending through the longitudinal bore of the intraosseous device.

2. The system of claim **1**, wherein the sensor comprises a pressure transducer configured to measure pressure.

3. The system of claim **2**, wherein the monitor is configured to detect when the pressure exceeds a preset value,

wherein monitor is further configured to sound an alert when the monitor detects that the pressure exceeds a preset value.

4. The system of claim **1**, wherein the sensor is configured to measure a plurality of parameters, the plurality of parameters comprising two or more of pressure, temperature, oxygen levels, carbon dioxide levels, and lactic acid concentrations.

5. The system of claim **4**, wherein the monitor is configured to detect when one or more parameters of the plurality of parameters fall outside of a desirable range.

6. The system of claim **1**, wherein the intraosseous device comprises a side port proximate to the tip, the side port configured to deliver a fluid into the bone marrow.

7. The system of claim **6**, further comprising a connector receptacle disposed proximate to the end opposite from the tip of the intraosseous device.

8. The system of claim **7**, wherein the connector receptacle comprises a Luer lock connection, the Luer lock connector configured to attach to a source of the fluid.

9. The system of claim **7**, wherein the connector receptacle has an outer diameter that is greater than an outer diameter of the intraosseous device.

10. The system of claim **1**, further comprising a supporting structure configured to prevent movement of the intraosseous device, the supporting structure comprising:

a body defining a longitudinal bore configured to receive the intraosseous device, the longitudinal bore having inner dimensions that correspond to exterior dimensions of the intraosseous device; and

at least one tab extending from the body.

11. The system of claim **10**, further comprising an attachment mechanism,

wherein the attachment mechanism is configured to engage the supporting structure,

wherein the attachment mechanism is configured to secure the supporting structure to a limb of a patient when the attachment mechanism is engaged with the support structure.

12. The system of claim **11**, wherein the at least one tab comprises a structure that is configured to engage with a corresponding structure formed on the attachment mechanism.

13. The system of claim **11**, wherein the attachment mechanism is sized to engage with a surface of the limb of the patient.

14. The system of claim **1**, wherein the tip comprises a tapered surface.

15. The system of claim **1**, wherein the intraosseous device comprises a tapered surface extending from the tip towards the end opposite from the tip, the tapered surface configured to form a fluid seal with the bone penetrated by the intraosseous device.

16. A system for monitoring performance of an intraosseous device, comprising:

an intraosseous device comprising:

a tip configured to penetrate bone and bone marrow such that the tip is disposed in the bone marrow;

an end opposite from the tip configured to be disposed outside of the bone marrow;

a longitudinal bore extending from the tip to the end opposite from the tip; and

a side port proximate to the tip and in fluid communication with the longitudinal bore;

a pressure transducer contained within the tip, the pressure transducer configured to measure pressure;

a monitor configured to record the pressure measured by the pressure transducer; and

an electrical conductor coupled to the pressure transducer and configured to transmit the pressure measured by the pressure transducer from the pressure transducer to the monitor, the electrical conductor extending through the longitudinal bore of the intraosseous device.

17. The system of claim **16**, wherein the intraosseous device is configured to deliver a fluid into the bone marrow.

18. The system of claim **17**, wherein the pressure transducer is configured to measure the pressure in an area of the bone marrow when the intraosseous device is delivering the fluid into the bone marrow.

19. The system of claim **17**, wherein the intraosseous device comprises a tapered surface extending from the tip towards the end opposite from the tip, the tapered surface configured to form a fluid seal with the bone penetrated by the intraosseous device.

20. The system of claim **17**, further comprising a seal assembly configured to isolate the electrical conductor from the fluid when the intraosseous device is delivering the fluid into the bone marrow.

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